HAWC-VERITAS (WCD-IACT)

Joint Work

What we learned

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Member of VERITAS and HAWC collaborations

Workshop on a Southern Hemisphere All-Sky Observatory, 2016 Nov

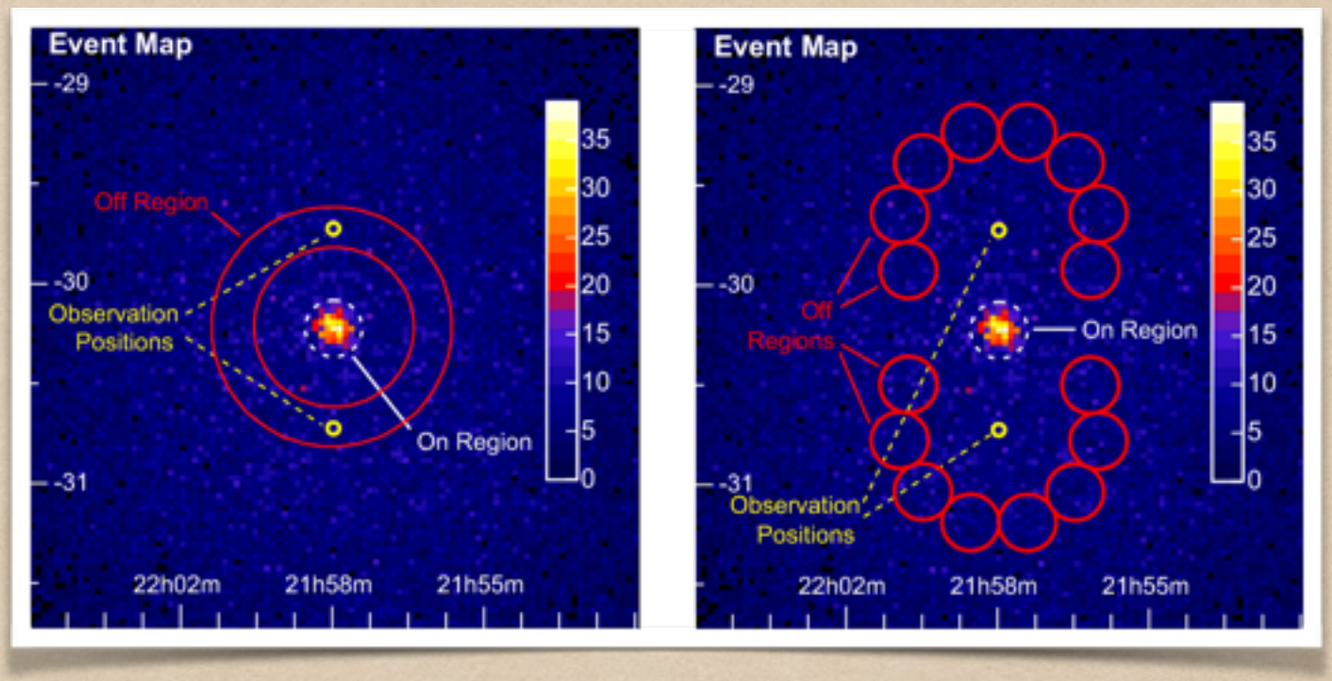
VERITAS Observatory

- Array of four Imaging Atmospheric Cherenkov Telescopes with pointing accuracy < 50 arcsec
- Detect gamma rays in the energy range 85 GeV - 30 TeV
- With an energy resolution of 15-25%, and angular resolution $R_{68\%}$ < 0.1 deg
- Able to detect 1% Crab source in ~25h
- VERITAS is located at +31° 40' 30.21"N 110° 57' 7.77”W
- Compared with HAWC +18° 59’ 41.0"N 97°18'27.2"W

VERITAS & HAWC are complimentary to each other

- HAWC is sensitive to higher energies, and there is a good over lap for cross calibration
- VERITAS compliments HAWC with better angular resolution, energy resolution and instantaneous sensitivity.
- HAWC compliments VERITAS with better duty cycle, aperture, sensitivity to extended sources.

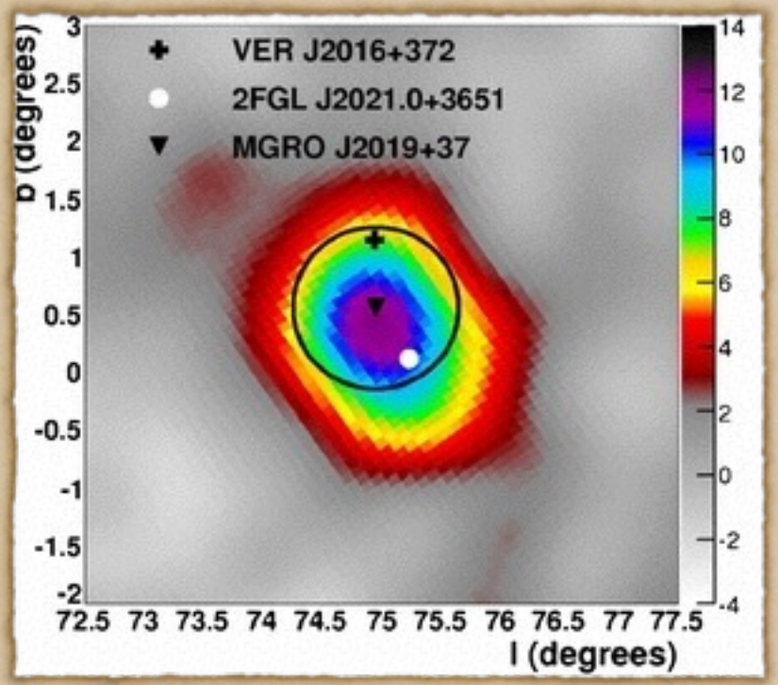
HAWC can help VERITAS to select targets



- VERITAS should know where to look
- In the standard analysis Off regions should be selected away from sources
- Two new techniques are under development, new techniques will have better sensitivity for extended source

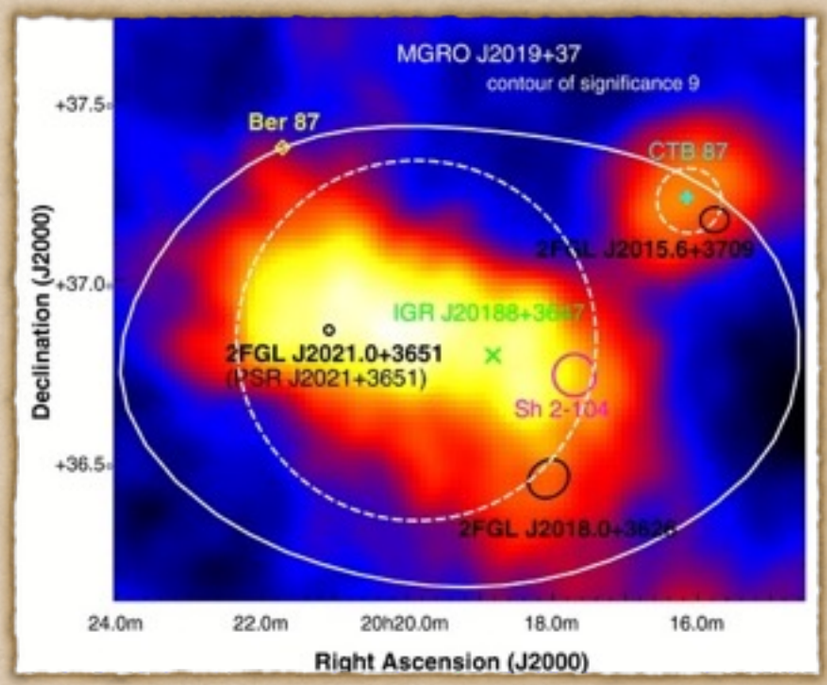
Disentangle sources

Milagro extended source MGRO J2019+37



This is what Milagro have seen

Abdo, A. A., et al. 2012, ApJ, *753*, 159

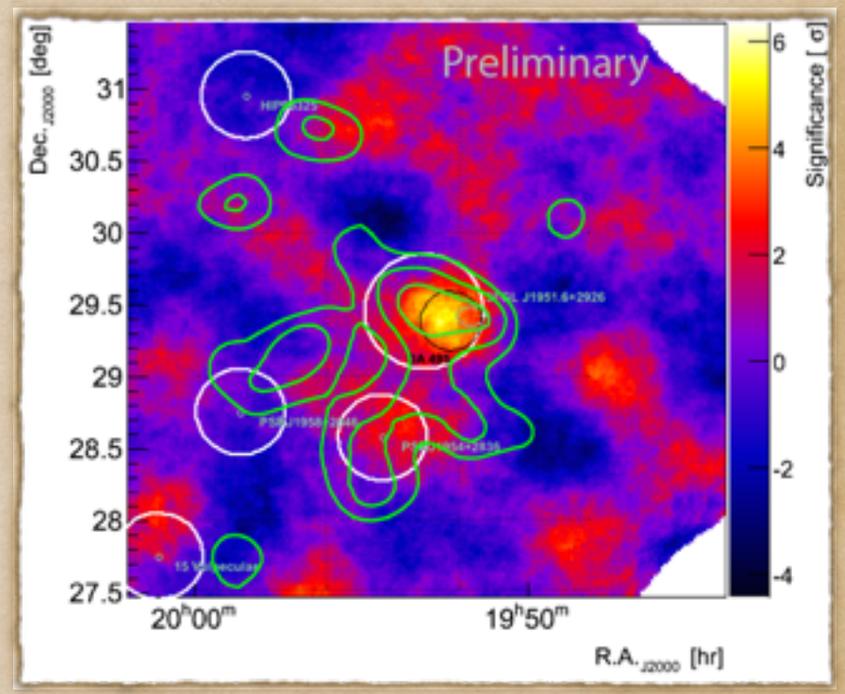


VERITAS detection

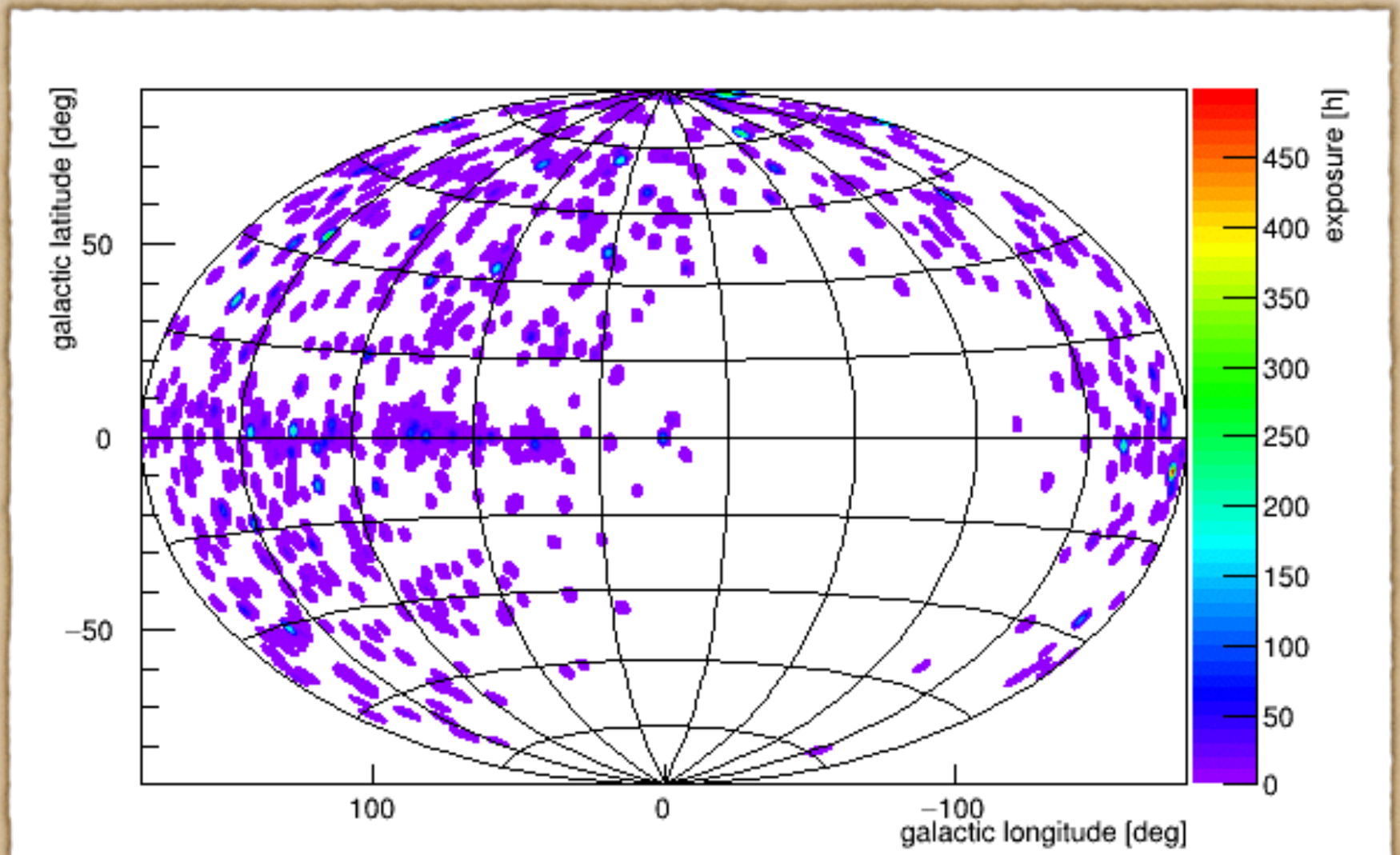
Aliu, E., et al. 2014, ApJ, *788*, 78

VERITAS Follow up of HAWC sources

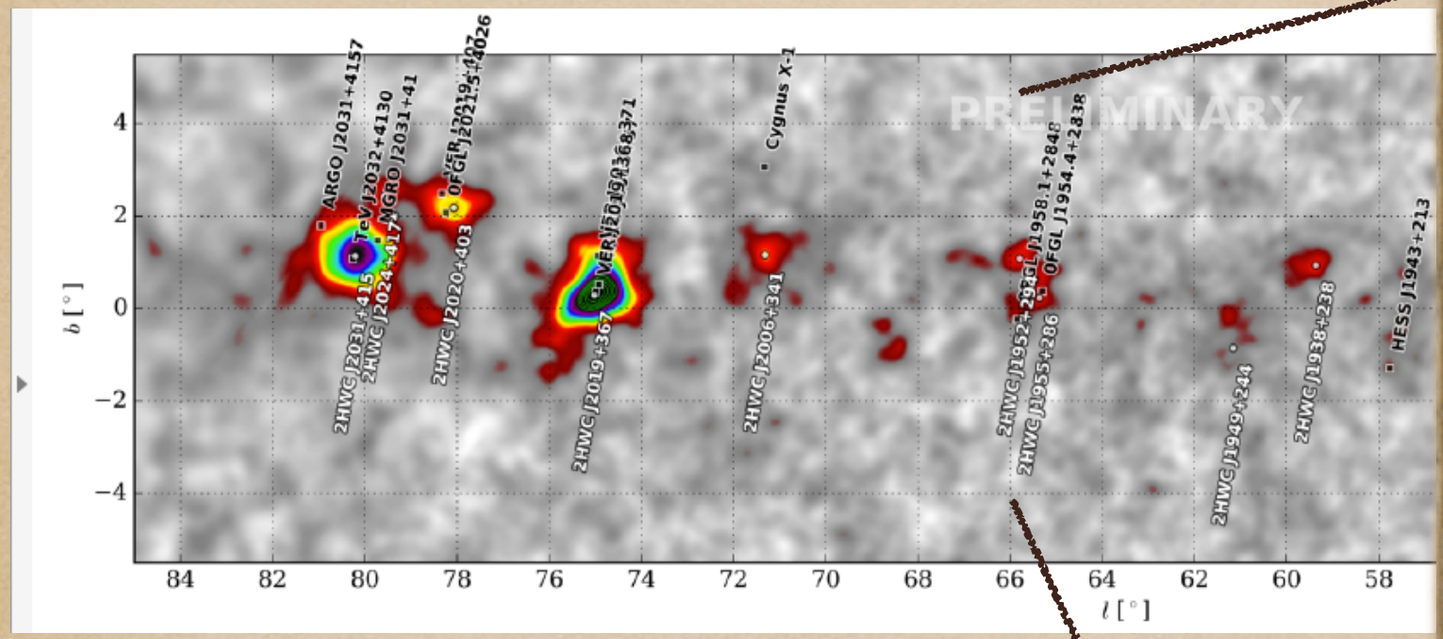
- With the better instantaneous sensitivity VERITAS could make measurements with a shorter exposure
- HAWC tells where and how (select the wobble, exclusion regions) to look
- Results from 1HWC (A. U. Abeysekara et al., ApJ. 817 (2016), 3.) follow up was published at 6th Fermi symposium
- Preliminary results from 2HWC follow up was presented at Gamma 2016 in Heidelberg
- VERITAS confirmed a 2HWC source; 2HWC J1952+294

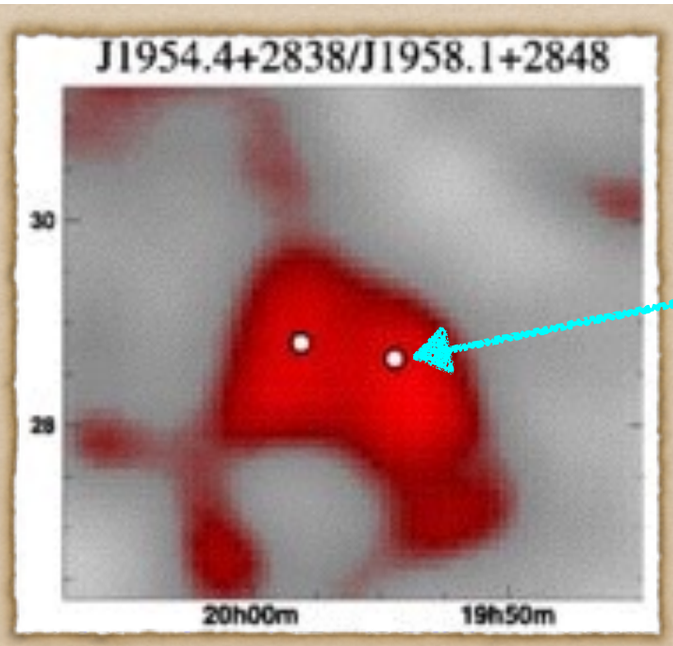


VERITAS has a smaller field of view
But we have been running for a decade



HAWC might see two point sources as a single source





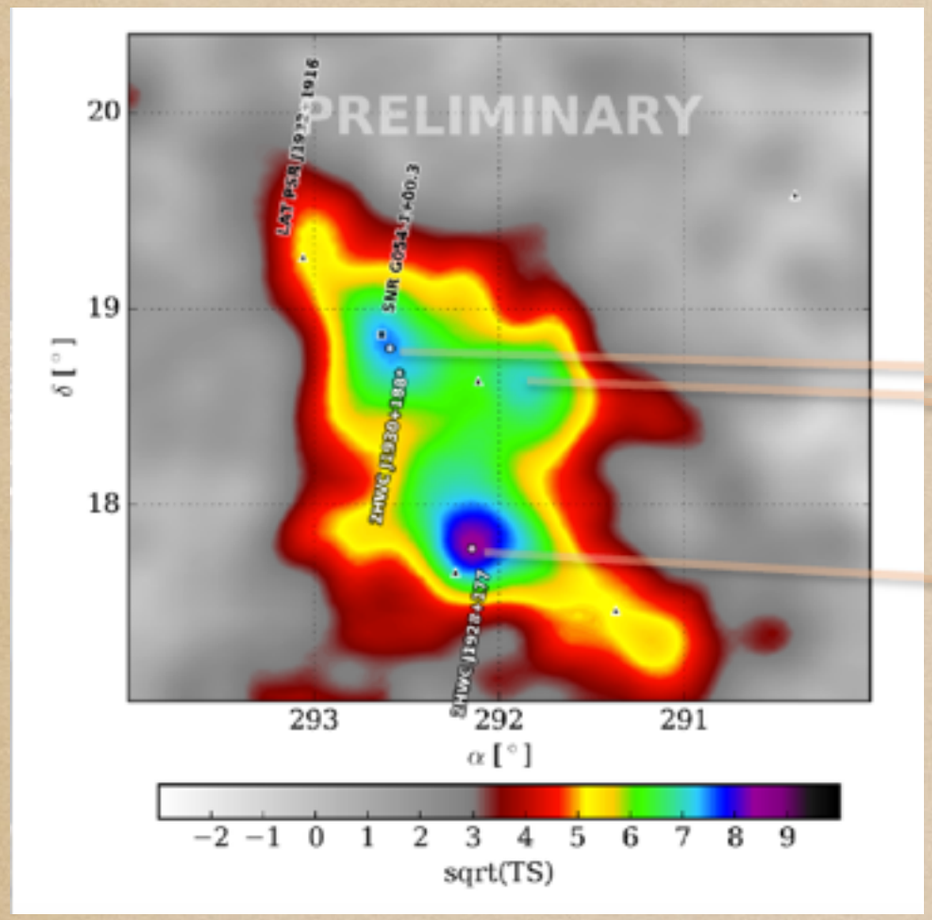
Milagro observed an excess of 4.3 sigma

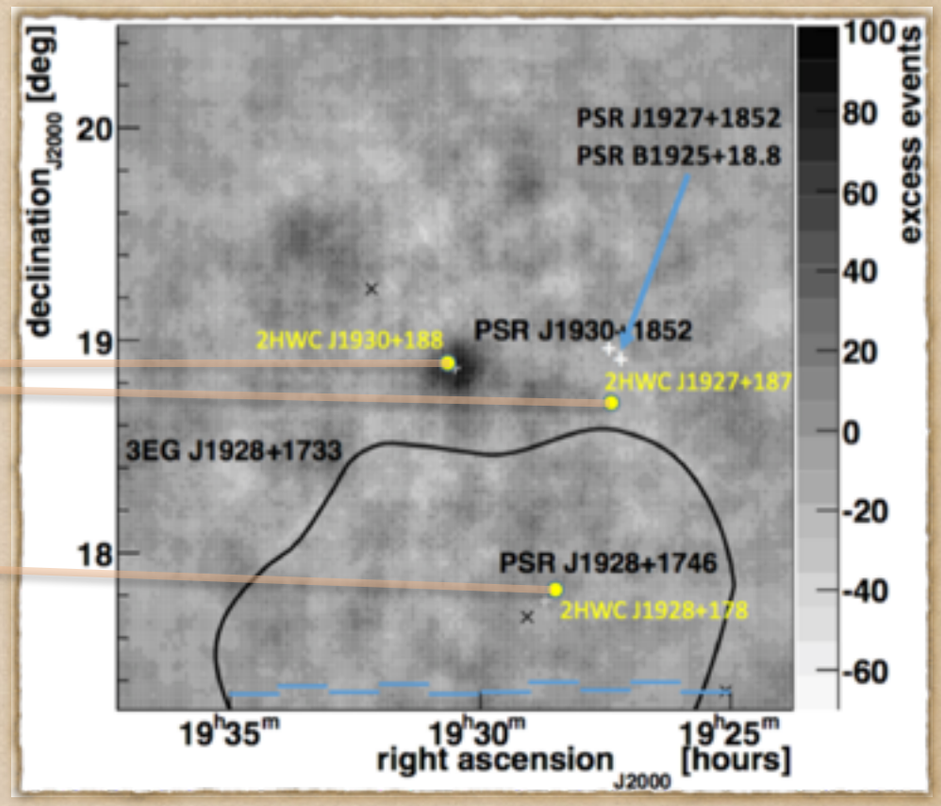
Abdo et.al. 2009 Ap.J.L. V 700, 2

HAWC might see two point sources as a single source

- Both 3FGL sources are Fermi-LAT detected pulsars
- Milagro observed 4.3 sigma
- MAGIC followed up this region but found no significant gamma-ray emission
- VERITAS followed up, but no new detection
- MAGIC suggested the existence of two weak PWNs associated with two PSRs. Milagro possibly seeing effective emission from both PWNs
- Deeper IACT observations will solve the mystery, HAWC has to tell where and how to look

Executioner region





[VERITAS, Acciari, et al. 2010]

- VERITAS does not see the brightest source for HAWC, 2HWC J1928+178
- VERITAS detected 2HWC J1930+188, which is the dimmer than 2HWC J1928+178
- Other two sources might be harder sources, or extended

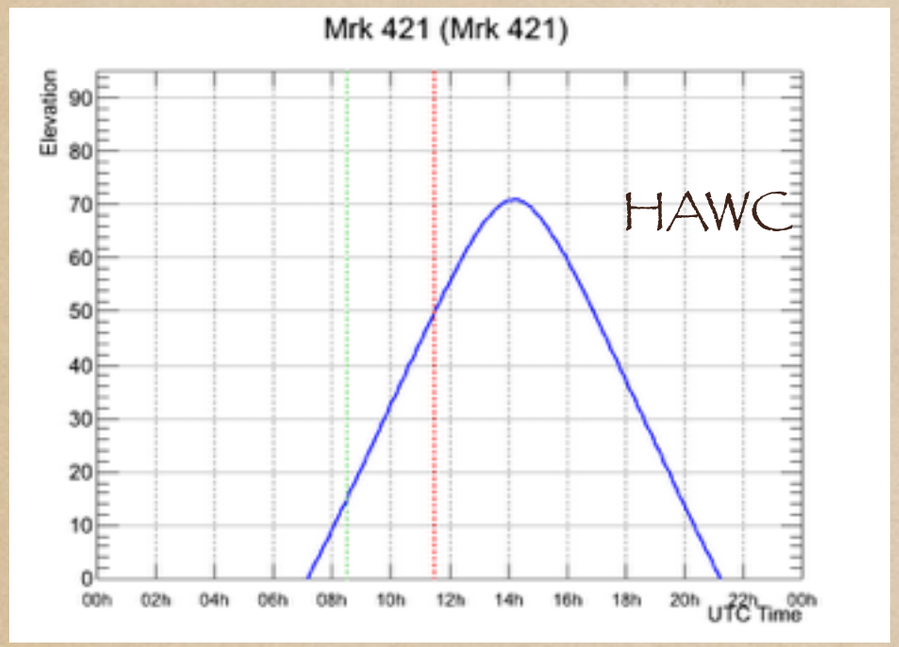
Geminga

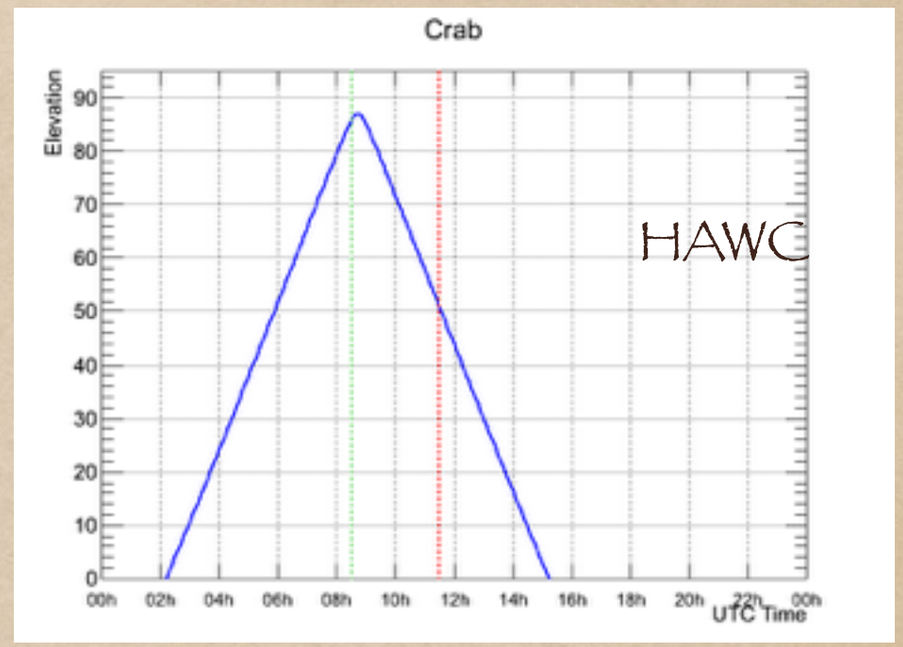
- Milagro have seen an extended source with an extra smoothing with a 1 degree Gaussian
- HAWC detected a finer structure
- No point source detection with VERITAS
- VERITAS new detection techniques Likelihood technique (arXiv:1508.07310) and Match Run Method (arXiv: 1509.04224) will be more sensitive to extended sources

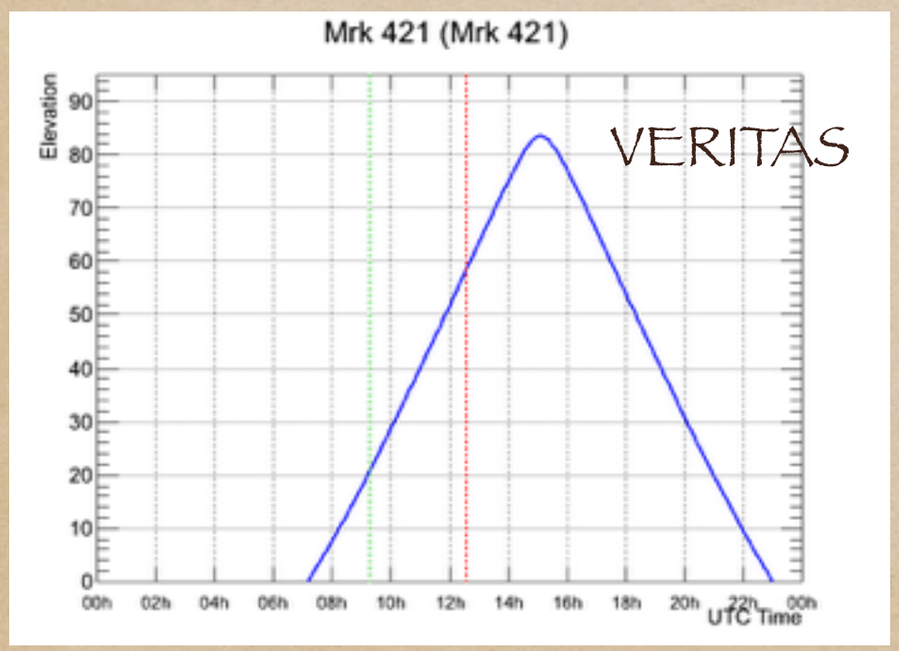
Where, How, and When

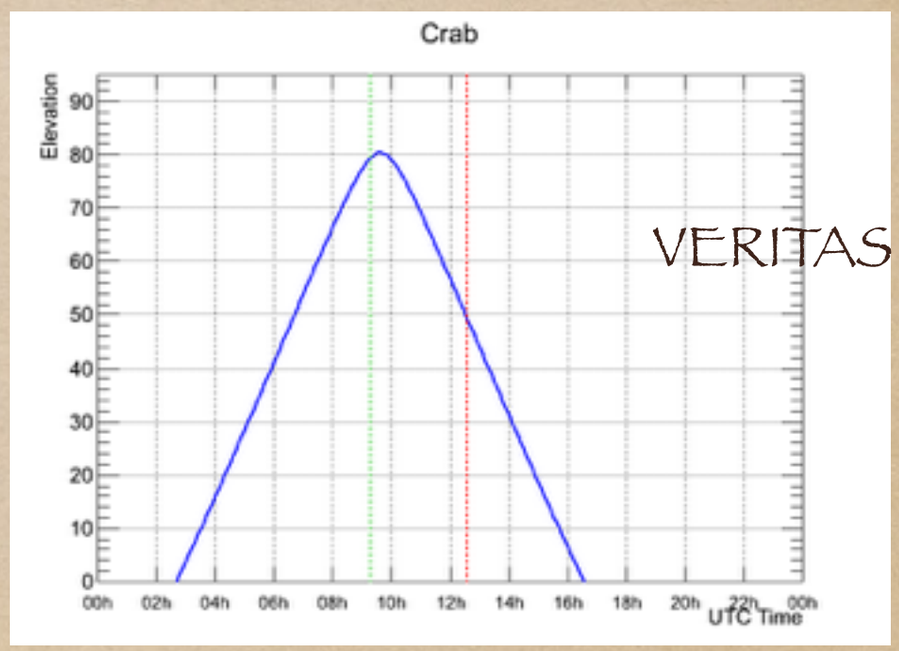
- VERITAS observed a list of TeV blazars consistently throughout the observation season
- Not only outstanding flares but also quiescent state measurements are important to understand Blazars
- HAWC has two different flare alert systems with different specifications
- HAWC alerts could tell VERITAS when to observe
- Observing GRBs is the highest priority of VERITAS
- VERITAS will also follow up HAWC GRB alerts

Sources rise and set approximately at the same time for both VERITAS and HAWC sites









CTA trigger? Continues coverage of transients?

Fermi-VERITAS-HAWC

Joint projects

- Cygnus regione
- Geminga
- EBL
- Cross calibrate VERITAS and HAWC using the standard candle Crab PWN
- Upper limits on VHE emission from GRBs
- TeV Binaries
- MGRO J1908 and MGRO J2019
- DM searches
  - Galactic Subhalos - self-annihilation or decay, these subhalos may be only visible at gamma-ray energies
  - dSph
  - Extended sources

Conclusion

- IACTs and WCDs are complimentary
- New path ways can be opened by combining two techniques

Thanks